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Research Article

Tilapia Culture in Geothermal Waters: A Case of Study in a Semi-Arid Region in North-Central Mexico

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Abstract: The objective of the present study was to implement and evaluate a semi-intensive Nile tilapia culture in a pond of 4, 900 m² serving with geothermal-water in a semi-arid region in the Central-North Plateau of Mexico. A total of 10,000 masculinized Nile tilapia (*Oreochromis niloticus*) fingerlings of 3.0±0.5 g of total body weight were introduced into the pond. The culture had duration of 10 months and during this time analysis of water quality, feeding and biometrical samples were realized and at the ending growth performance indicators were calculated. The results indicated that Nile tilapia at the end of the experiment reached a mean of 28 cm of total length and a mean of 360 g in total body weight, with a survival rate of 87%. The total yield obtained was of 6,000 kg/ha. This study demonstrated a high potential of Nile tilapia in semi-intensive culture in geothermal-waters ponds.

Keywords: Geothermal water, growth performance, Nile tilapia, semi-arid region, semi-intensive culture

INTRODUCTION

The state of Aguascalientes is located at the North-Central Mexico Plateau, in a semi-arid region and has long been recognized by their abundance of “hot spots” of geothermal origin. In fact, the name of the state means “hot waters”. The hot springs are usually utilized for curative purposes, animal and human consumption and agriculture; nevertheless, hot springs in Aguascalientes have been little employed in aquaculture activities.

In the past several years, tilapia culture has been a fastest growing in the state, in spite of their semi-arid climatic conditions, which are inadequate to maintain a long growth-period of tilapia. For this reason, the tilapia producers in the state have implemented an expensive facility to keep water temperature above 25°C in the winter season. This temperature has been achieved through the use of greenhouses or plastic domes. Under these conditions, it is possible to obtain table-size fish in 12 months or more, however, this is considered a long growing season, which drastically affects the economic profits of fish farmers. An alternative that may be important in Aguascalientes is the use of geothermal water to improve fish production. The benefit of a controlled rearing temperature in aquaculture operations can increase growth rates by 50 to 100% raising the number of harvest per year and

reducing remarkably the growth fish period (Lienau, 1991).

Currently, the available information on geothermal-based tilapia culture systems is very limited worldwide. In the USA, a number of farms had used geothermal water sources to raise tilapia in Idaho, Arizona, California, New Mexico and Mississippi (Watanabe *et al.*, 2002). Hargreaves (2000) described an intensive grow out facility in Mississippi, which use geothermal water at 26°C for tilapia culture. Azaza *et al.* (2008), reported positive effects of water temperature on growth and feed utilization in Nile tilapia *Oreochromis niloticus* in Tunisia at 26 to 30°C. The geothermal heat has been an important factor in the increased production of tilapia. Pumped or flowing naturally from artesian sources, are used directly as a culture medium, or as a heat supply for indirect temperature control through heat exchangers. This permits geothermal based facilities to grow fish faster and during any seasons of the year (Zachritz and Rafferty, 2000). Many farms around the Salton Sea and Imperial Valley area of Southern California use geothermal fluids (Rafferty, 1999). Lund (2003) reported the existence of 18 geothermal district-heating systems in USA where 45 sites in 11 states realized aquaculture in pond and raceways. The largest concentration of geothermal aquaculture facilities is in the Imperial Valley, southern California, where

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approximately 3.6 million kg of tilapia, catfish and hybrid striped bass are raising in 12 facilities.

In México there is not information available on tilapia culture with geothermal waters, therefore the goal of the present study was to implement and evaluate a Nile tilapia semi-intensive culture under a made-man pond served with a semi-continuous flow of geothermal water.

MATERIALS AND METHODS

The pond studied is located at the Centro de Ciencias Agropecuarias at the Universidad Autónoma de Aguascalientes located in Jesús María, Aguascalientes, Mexico. The pond was remodelled in June of 2010 from an old pond, which was used for more than 30 years as a water reservoir for irrigation agriculture. The pond is located in a typical semi-arid region at 1,915 masl at 21°58'20.65" N and 102°21'41.26" W. It has a squared form with N-S orientation. Pond dimensions are 70×70 m covering 4,900 m² with a maximum depth of 4.0 m at the southwest side. Maximum water volume is 14,700 m³ and the minimum is around 6,480 m³. Water volume of the pond over the year is regulated by the irrigation of crops such as alfalfa (*Medicago sativa*), corn (*Zea mays*), oat (*Avena sativa*), chilli peppers (*Capsicum spp.*), bean (*Phaseolus spp.*) and others crops.

The pond receive water from three hot wheels connected by 6"hydraulic PVC tubes that maintain flows of 769, 383 and 690 L/minute, respectively. Water temperatures injected into pond reach 35, 30 and 29°C, one-to-one, all year around.

A total of 10,000 masculinized fingerlings Nile tilapia (*Oreochromis niloticus*) strain Stirling with average total body weight and length of 3.0±0.5 g and 2.5±1.5 cm, respectively, were introduced into the pond on August 19, 2011. Tilapia fingerlings was obtained from Acuímor Farm in Morelos, State, Mexico and carrier to Aguascalientes in 50 L plastic bags containing 800 fingerlings each plus oxygen. The tilapia fingerlings were acclimated for two hours and delivered into the pond.

Water quality of the pond was analysed during the tilapia-growing period. Water temperature, dissolved oxygen, salinity, conductivity and specific conductivity were determined five days a week with an oxymeter YSI model 85 (Yellow Spring Instruments, Ohio, USA). Total nitrogen ammonia (TAN), nitrite content and pH were also determined once a week with a multi parameter photometer (Hanna model HI83203 Series 2008) and a pH meter (Hanna model HI991001). Tilapia feeding was a follow:

- Fingerlings did not receive artificial feeding during the first four growing months in the pond (from August 19 to December 2011); during this period, fingerlings feed only on microorganisms naturally produced in the pond

- Growing months 5 and 6 (January and February 2012) fingerlings were feed on 1.5 mm extruded Purina NUTRIPEC 4415 C (44% of crude protein, 15.0% of lipids, 3% of crude fibre and 19% of NFE)
- From March to the end of the culture, tilapia was feed on Aqua Premier 3205 which has 3.5 mm (32% of CP, 4% of L, 5% of CF and 41% of NFE). Daily feed requirements over the growing cycle was based on 2% of total body weight; feed was provided twice a day, one at 10:00 am and the other at 5:00 pm.

Six biometrical analyses were conducted over the growing cycle, one at the beginning in August of 2011 and the rest in January, February, March, April and May 2012. Tilapia samples were caught using two round nets or esparavel having a mesh size of 5.5 and 7.5 cm, respectively. Samples of 40 organisms each were taken and placed in a 68-L plastic recipient containing 40 L of pond water plus 25 mL of 10% benzocaine as anaesthetic solution. Total Length (TL) in centimetres and Total Body Weight (BW) in grams were determined for each fish; TL was registered with a conventional ichthyometer (0.1 mm) and TBW with a compact digital scale (Ohaus CS200).

The following 13 indicators of growth performance were calculated according with Ergün *et al.* (2010). Initial and final body weight (iBW and fBW, g), gain of body weight (GBW, g), daily gain of BW (g/day), initial and final total length (iTTL and fTL, cm), gain of total length (GTL, cm), daily gain of TL (cm/day), specific growth rate (SGR, %), total consumption of feed (TCF, kg), condition factor (K), feed conversion rate (FCR) and survival (S, %). Values of SGR, TCF, K and FCR were calculated as follows:

$$SGR = (\ln fBW - \ln iBW / T) * 100$$

Where,

- Ln = Natural logarithm
- fBW = Final body weight
- iBW = Initial body weight
- T = Time of culture in days
- GfBW = Gain of final body weight
- K = $BW / L^3 * 100$.
- FCR = GfBW(kg)/TCF (kg)
- TCF = Σ TCF daily in kg

All measurements were organized in an Excel file. General statistics of the 13 indicators of performance (mean, standard deviation, coefficient of variation) were calculated and summarized. Growth performance of tilapia under a geothermal system in Aguascalientes was analysed through simple analysis in order to model the variation of TBW and TL over the growing cycle.

Commercial harvesting of tilapia began on June 31, 2012 when fish reached ten months in the pond and a mean TBW of 360 g. About 50 kg of fish was harvested once a week with a 5.5 cm static gill net.

RESULTS AND DISCUSSION

The information about tilapia growth under different conditions and culture systems around the world is quite large; ponds, cages and recirculation aquaculture systems are the most important and common (Alceste, 2000; Fitzsimmons, 2000a and b; Guerrero, 2001; Guerrero, 2002; Irz, 2002; Gupta and Acosta, 2004). Most published papers mention that tilapia culture in tropical and subtropical areas is usually under warm waters, whose temperature is close to 25°C across the year. Under these water temperatures, tilapia reaches a commercial size in 6 to 8 months of culture. On the other hand, little information is available for arid and semi-arid regions. According to air temperature, arid and semiarid regions usually present two well defined seasons: a warm summer season and a cold winter season.

The results of water quality parameters using geothermal waters registered along the experimental period are shown in Table 1. Across ten months of culture the values of dissolved oxygen, water temperature, pH and the others parameters evaluated were continuous presenting slight variations and there were not observed critical conditions even in the cold season. According with Arredondo and Ponce (2011), mean values of water temperature (23.3°C), dissolved oxygen (above 5 mg/L), pH (6.5 to 7.5), TAN (<0.0

mg/L) and nitrite (<0.6 mg/L) stayed within optimal ranges. These mean values indicated that water quality was keeping in adequate conditions for tilapia growth. Air temperatures registered by the local meteorological station during the cold winter season (December, January and February) was below 0°C, however, the minimum water temperature registered by the pond over the winter was 17.9°C. In fact, the lowest temperature was registered when water pumping for crop irrigation was off during the rainy days of December and January. Water temperature below 11°C, is critical and may be lethal for Tilapia. Hephher and Pruginin (1981 and 1982) reported inhibition of growth rates in the greenhouses during the cold months. Wohlfarth and Hulata (1983) denoted that tilapia quit breeding at 22°C and ceased eating at 20°C. The results obtained in geothermal waters in Aguascalientes showed that Nile tilapia kept feeding at 18°C. Although Cnaani *et al.* (2000) observed different levels of tolerance of low water temperatures among species of tilapia. They mentioned that variation in tolerance to low water temperature in tilapia was under genetic control, with a dominant component based on hybrid-parent similarity. Tolerance to low water temperature in tilapia may be inherited from generation to generation.

In this experiment Nile tilapia exhibited good growth rate along 10 months of culture. In the Fig. 1 and 2 are presented growth curves in TL and TBW.

Table 1: Results of water quality parameters register in the pond during the culture time

Parameters/Statistics	Mean	S.D.	Minimum	Maximum	CV (%)	Optimal values ¹
DO (mg/L)	5.4	1.5	1.26	10.6	28	3-5
DO (% sat.)	64.7	20.4	15.0	140.6	32	60-100
Temperature °C	23.3	2.6	17.9	30.3	11	24-29
C (µS/cm)	827	41.2	708	933	5	5-100
SC (µS/cm) at 25°C	878	40.6	750	1017	5	5-100
S (g/L)	0.4	0.1	0.4	0.5	4	0-20
pH	7.0	0.2	6.8	7.3	3	6.5-7.5
TAN (mg/L)	0.20	0.0	0.10	0.20	0	<0.8
N-NO ₂ ⁻ (mg/L)	0.01	0.0	0.00	0.04	0	<0.6
P-PO ₃ ⁻³ (mg/L)	0.70	0.3	0.26	0.97	43	1-5
Ch (mg/L)	0.0	0.0	0.0	0.02	0	<60

¹ = Arredondo and Ponce (2011). DO = dissolved oxygen; C = Conductivity; SC = Specific conductivity adjusted at 25°C; S = Salinity; TAN = Total Nitrogen Ammonia (NH₃ + NH₄⁺); N-NO₂⁻ = Nitrite; P-PO₃⁻³ = Soluble orthophosphates; Ch = Chloride; CV (%) = Coefficient of variation

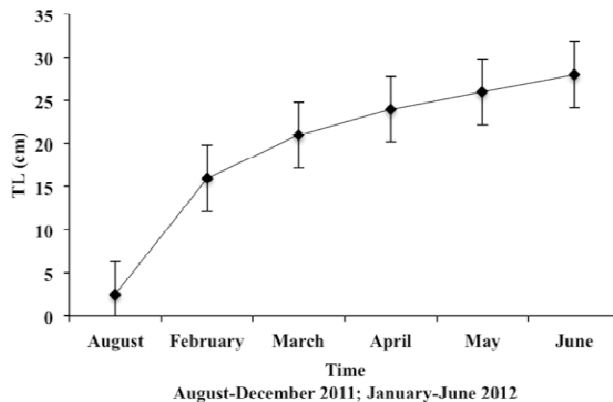


Fig. 1: Growth of Nile tilapia in total length (TL) in a semi-intensive culture in geothermal water pond during 10 months

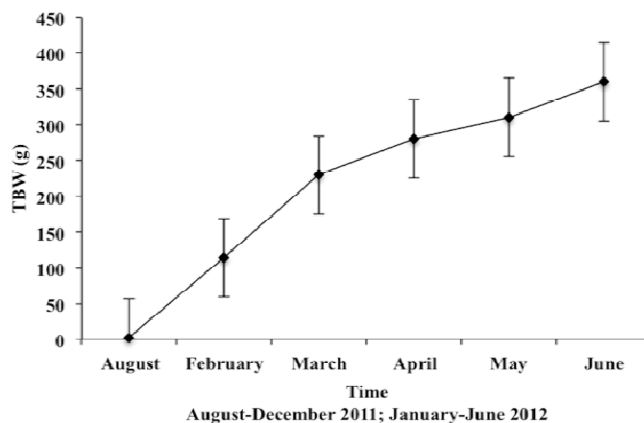


Fig. 2: Grown of Nile tilapia in total body weight (BW) in a semi-intensive culture in geothermal water pond during 10 months

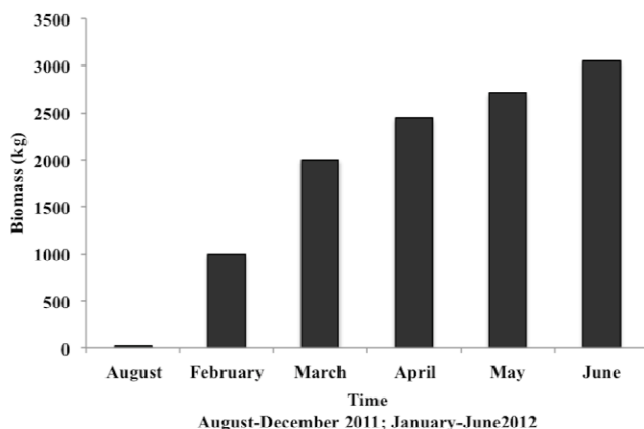


Fig. 3: Increase of biomass of Nile tilapia under semi-intensive conditions during 10 months of culture period

The organisms reached in that time a mean size of 28 cm of TL and a mean TBW of 360 g. Tilapia farmers in Aguascalientes face problems of low water temperatures over the winter; when water temperature descends as low as 8°C, therefore, a modification of the culture system and facilities are necessary to avoid low water temperatures during the winter. Greenhouses and closed domes can be used to retain water temperatures and growing conditions within optimal ranges for commercial production. Tilapia growth rates are strongly affected by water temperature therefore tilapia culture from fingerlings to commercial size can take up 12 months and even longer if water temperature is below optimal range. Based on the growth indicators, our production system could be considered of superior efficiency. It took ten months from fingerlings introduction to commercial size. However, more research is required to better understand and improve the system in order to keep water temperature and quality within optimal.

The total yield obtained in the pond under the experimental semi intensive culture conditions reached three metric tons/ha as can be appreciated in the Fig. 3. Were observed an increase tendency along the culture time.

The semi-culture realized in this study reached similar yields to others countries and continents. For example, in Israel, masculinized fry of hybrid (*O. niloticus* x *O. aureus*) are intensive-cultured with common carp *Cyprinus carpio* applying constant aeration; under this condition tilapia reach 400 g (Rawling *et al.*, 2009). In Africa, higher production is obtained in small scale in earthen ponds in monoculture obtaining a yield of 500 kg/ha (Jamu, 2001). In Brazil, in small ponds of 0.1 ha storage with males reverted of tilapia in monoculture and in polyculture with common carps and Chinese carps the yield fluctuated between 3 or 4 tons/ha/year (Lovshin, 2000) and in Panama and Honduras in ponds of similar size in densities of 10,000 to 30,000 fishes per hectare they reach yields until 5 tons/ha/year (Teichert-Coddington and Green, 1997). In this study maintaining a density of 20,000/ha of masculinised fry tilapia, the yield reached 6 tons/ha in a semi-intensive culture, demonstrating a high potential using geothermal waters in ponds that target objective is the agriculture activities.

The results of growth performance indicators are shown in Table 2. This indicated significant results with respect TBW and LT increase during 270 days of

Table 2: Growth performance indicators obtained in this work and expected values in a Nile tilapia semi-intensive culture in geothermal waters in Aguascalientes, México

Indicators	Reported values in this work	Expected values.
Months of culture	10	10
Mean initial total body weight (g)	3.0	4.0
Mean final total body weight (g)	360	400
Gain of TBW (g)	358	396
Mean initial total length (cm)	2.5	3.5
Mean final total length (cm)	28.0	29.5
Gain of TL (cm)	25.5	26.0
Daily gain of TBW (g/day)	1.3	1.5
Daily gain of TL (cm/day)	0.10	0.11
Specific growth rate (%/day)	1.8	2.0
Condition factor	1.6	1.5
Feed conversion ratio	0.5	0.5
Survival rate (%)	87	90
Yield (kg/ha)	6,000	7,000

culture, maintaining a daily gain of TBW and TL of 1.3 g and 0.10 cm, respectively. The survival rate and total yield may be considered high (87% and 6,000 kg respectively) for the culture conditions.

It is very important to know the performance indicators in different aquaculture systems, to realize comparison under different climatic conditions. This indicators permit locate the culture inside others similar experiences realized in other countries and continents. However, not all data are available and the main factors evaluated in these studies are the density and yield (Popma and Lovshin, 1995; Alceste, 2000; Fitzsimmons, 2000; Watanabe *et al.*, 2002; Modadugu and Acosta, 2004; Belton *et al.*, 2009). When it is necessary compare some indicators in cultures, for example Specific Growth Rate (SGR), Feed Conversion Ratio (FCR) and Condition factor (K) are not available. Generally, these indicators are used in experimental nutrition researches in relative short times between five or ten weeks and for this reason is difficult the comparisons in cultures of more than 200 days. However some data permit to have an idea of the growth. Ng and Wang (2011) evaluated the inclusion of crude palm oil and their effect on the growth performance of *O. niloticus* in an experiment of 175 days. In the four diets tested reported a specific growth rate (SGR) fluctuating between 1.07 and 1.23%/day and a condition factor (K) of 1.8 and 1.9. Rawling *et al.* (2009) in a short experiment of 70 days evaluated a supplementary feed (Sangrovit) reported a SGR from 3.94 to 4.05%/day with a FCR from 1.03 to 1.11. Comparing these data with the results obtained in this study the mean values of SGR and K were higher than those reported by Ng and Wang (2011), on contrary SGR was lower than those reported by Rawling *et al.* (2009) and K value lower. This information confirms the difficult to do comparison when the objectives are different and it is necessary unified criterions.

CONCLUSION

The use of geothermal waters in ponds may improve the Nile tilapia semi-intensive culture in semi-arid regions, maintaining a constant growth rate and

reaching 6 tons/ha in ten months of culture. This technology offers a unique opportunity for increase profits in agriculture activities.

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